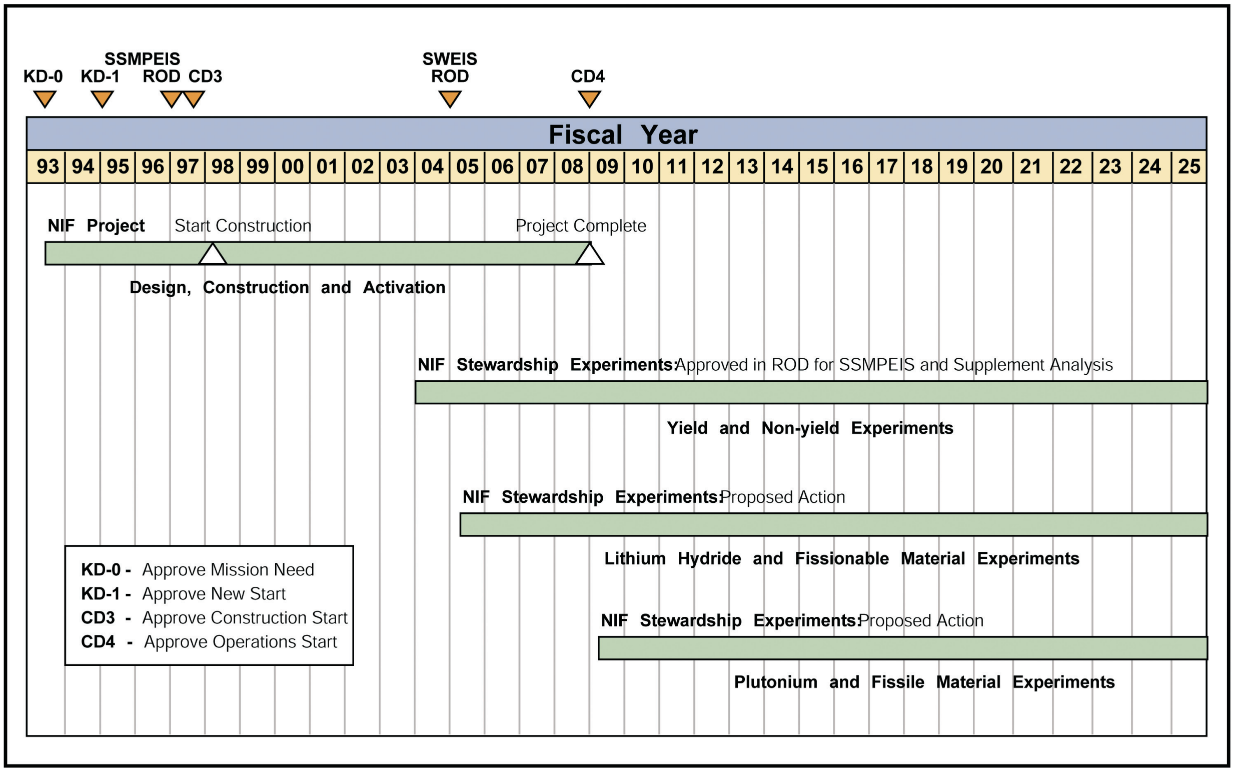

Source: Original.
Note: See page 20 for a discussion of the terms fissile and fissionable.

FIGURE M.1.3–1.—*National Ignition Facility Timeline and Relation to Use of Certain Proposed Materials*

M.2 PURPOSE AND NEED

M.2.1 National Ignition Facility Purpose and Need

In January 1993, the Secretary of Energy approved the justification of mission need for the NIF as a part of approval of Key Decision 0 (Reis 1993). Figure M.1.3–1 shows the timeline for approval of the key decisions for NIF. The justification stated that the NIF was being proposed to support the inertial confinement fusion program requirement to achieve ignition and propagation of thermonuclear fusion and burn. In October 1994, the Secretary of Energy approved Key Decision 1 that verified the mission need for the NIF (Reis 1994). The mission areas identified in Key Decision 1 were nuclear weapons physics, inertial fusion energy science and technology, and other applications. The nuclear weapons physics discussion stated that "In the absence of underground testing, the NIF would be a critical tool for the Department's Science-Based Stockpile Stewardship Program."

In 1996, DOE changed terminology from "Key Decision" to "Critical Decision."[1] As indicated in the footnote, the terminology went from Key Decision 1 to Critical Decision 3.

In February 1997, the Secretary of Energy approved Critical Decision 3 (Reis 1997), which affirmed the need for the NIF and stated that "The National Ignition Facility is a key element of Defense Programs' science-based Stockpile Stewardship and Management Program." In September 2000, the Secretary of Energy certified to Congress that: "The National Ignition Facility supports the Stockpile Stewardship Program (SSP), and is a vital element of it in three important ways: (1) the experimental study of issues of stockpile aging or refurbishment; (2) weapons science and code development; and (3) attracting and training the exceptional scientific talent required to sustain the program over the long term" (Richardson 2000).

In 2001, former DOE/NNSA Administrator, General John A. Gordon, certified to Congress (Gordon 2001) the importance of the NIF to the SSP based, in part, on NNSA High-Energy-Density Physics (HEDP) Report (DOE 2001h). This report concluded that:

- "A vital HEDP Program is an essential component of the SSP. The baseline HEDP Program, including the 192-beam NIF meets the SSP requirements."
- "Ignition is an important goal for the HEDP Program, the SSP and the national scientific community."
- "A laboratory ignition source is the only known means available to examine thermonuclear burn in the laboratory."
- "The intent is to produce thermonuclear burn that, for a few trillionths of a second, produces some of the conditions found only in the center of stars and in the core of an exploding nuclear weapon. Achieving this ignition outside of a nuclear device will be a landmark achievement for the SSP."

As indicated above, the NIF provides a unique capability for DOE/NNSA's science-based stewardship of the nuclear weapons stockpile. Planned experiments on the NIF, at temperatures and pressures approaching those that occur in nuclear weapon detonations, will provide scientific data needed to verify certain aspects of sophisticated computer models. These computer models are needed to simulate weapons performance and assess the reliability and performance of the Nation's nuclear weapons stockpile. Specially designed experiments on the NIF will address issues of modeling or physics that are of concern because of changes in weapons due to aging or remanufacture. They will also provide a unique source of radiation for studies of nuclear weapon effects; i.e., the effects of radiation on nuclear explosive package, control systems and electronics. The NIF will attract and challenge top scientific and engineering talent to address the elements of physical understanding as those necessary for stewardship of the nuclear stockpile.

To support NNSA's ongoing program of weapons assessment, it is important to have the NIF provide experimental data before the end of the decade. The NIF experiments will address, to various degrees, certain weapons issues connected with fusion ignition, thermonuclear burn, and

[1] The correlations between Key Decisions and Critical Decisions are: Key Decision 0 (approval of mission need) = Critical Decision 0 (approval of mission need); Key Decision 1 (approval to start design) = Critical Decision 1 (approval of preliminary baseline range); Key Decision 2 (approval to start final design) = Critical Decision 2 (approval of performance baseline): Key Decision 3 (approval to start construction) = Critical Decision 3 (approval to start construction); and Key Decision 4 (project completion) = Critical Decision 4 (approval to start operation and project closeout).

boosting; weapon effects; radiation transport; and secondary implosion, ignition, and output. Most of these processes occur at very high energy density; i.e., at high temperatures and pressures, and are relevant to a weapon's reliability and performance. Ignition and other experiments at NIF will allow assessment of issues critical to the operation of our modern nuclear weapons stockpile.

As a multipurpose facility, the NIF also is important to the Nation's energy and basic science missions. The NIF data could indicate whether inertial confinement fusion can be a viable source of electric power in the future. Achieving ignition, optimizing target performance, and providing initial data on fusion reactor materials could allow sound decisions to be made concerning development of an inertial fusion energy demonstration facility.

NIF experiments will achieve temperatures and pressures that exist in the sun and other stars, providing new laboratory capabilities for exploring basic high-energy-density physics issues in areas such as astrophysics and plasma physics (NAS 2003a, NAS 2003b).

M.2.2 Physical Processes of Nuclear Weapons

As indicated in Section M.2.1, planned experiments on the NIF will be conducted at temperatures and pressures approaching those that occur in nuclear weapon detonations and will provide scientific data needed to verify certain aspects of sophisticated computer models. The following unclassified summary of the operation of a nuclear weapon should facilitate understanding of the need for the NIF in relation to the SSP in general.

The relevant physical processes that occur in nuclear weapons or in the immediate environment of an ongoing nuclear explosion can be divided into the following processes:

1. Detonation of high explosive and implosion of fissile materials
2. Conditions for criticality of fissile material
3. Fusion ignition and boosting
4. Radiation transport
5. Secondary implosion
6. Secondary ignition, burn, and output
7. Nuclear weapon effects on other systems

Modern thermonuclear weapons consist of two stages: a primary stage, fission trigger, and a secondary stage, fusion. The primary stage contains a subcritical “pit” of fissile material, generally plutonium, surrounded by a layer of chemical high explosives. The high explosive is detonated, burns rapidly, and compresses the pit. To increase efficiency, modern weapon primaries can employ a process called boosting. In boosted primaries, the pit contains the hydrogen isotopes deuterium and tritium.

The purpose of the primary stage is to produce enough energy in the form of radiation to implode the secondary stage resulting in thermonuclear ignition and burn. The secondary stage produces high yield for modern U.S. strategic weapons. The terms ignition and burn will be used to indicate the process in which fusion fuel is ignited and undergoes self-sustaining fusion and burn.

M.2.3 National Ignition Facility Experimental Capabilities

The following discussion focuses on how NIF will be used to evaluate weapons concerns relevant to the physical processes listed in M.2.2. Experiments conducted to examine the phenomena below address issues associated with items 3 through 7 on the above list. Specific experiments can be conducted on the NIF with weapon materials to measure relevant equations of state, such as what pressures are created at high temperatures; opacity, i.e., how a material absorbs and emits radiation; and hydrodynamics, i.e., how a material moves in response to forces applied.

Experiments will be conducted on the NIF to examine the growth and control of hydrodynamic instabilities, which are important both in making inertial confinement fusion targets ignite and burn and in making nuclear weapons perform reliably. Hydrodynamic instabilities ultimately lead to mixing of some quantity of one material with another.

High temperature transport of radiation in complex geometries and materials can be examined to test the ability of computer models to predict this transport. Deposition and re-emission of radiation and the general transport problem within weapons constitute a complex process. This process must also be understood in order to predict the transport of radiation necessary to ignite inertial confinement fusion targets.

Output calculations must be done on the inertial confinement fusion ignition targets so that the performance of the target can be properly measured. Again, however, specific targets can be designed to alter the output radiation. These experiments can be used to test the computer codes used to calculate the output of weapons.

NIF targets, either the basic type for ignition or specially designed ones, would produce x-rays, neutrons, gamma rays, and other radiation. These emissions can be used to assess the consequences of nuclear effects in electronic systems or other hardware intentionally exposed to these radiations. The survivability of military hardware subjected to various nuclear effects is an important factor in ensuring reliability of that hardware.

If the stockpile surveillance program reveals an unanticipated change due to aging or remanufacture, a weapons expert can estimate which of the weapons physics processes discussed in M.2.2 could be affected. If any of the high-energy-density processes could be affected, then a NIF experiment could be designed to measure the physical properties of the change.

The nuclear weapons expected to remain in the stockpile are aging beyond their original design lifetime. It is important to have the NIF in place and producing experimental results successfully as soon as possible to help validate new computer models and otherwise support NNSA's ongoing nuclear weapons assessment activities.

M.2.4 Purpose and Need for the Use of Proposed Materials in the National Ignition Facility

M.2.4.1 *High-Energy-Density Physics Program Needs*

The High-Energy-Density Physics Study Report (DOE 2001h) recommended that the possibility of using special nuclear materials, defined as enriched uranium and plutonium, in experiments on the NIF should be examined in addition to experiments already planned for NIF (Section 2.3). This appendix evaluates the safety and environmental effects of the use of these materials in experiments on the NIF.

In the absence of underground nuclear testing, the SSP must continually surveil, maintain, and refurbish weapons in order to certify their safety, performance, and reliability. This is done based on the ability of scientists to evaluate problems using scientific calculations that have been validated with experimental data from the NIF and other SSP facilities and using archival nuclear weapons test data.

The approach to weapon assessment and certification by the weapons laboratories involves two major steps. The first is to identify all significant potential failure modes by using scientific and engineering judgment, results from past nuclear tests, aboveground tests and experiments, surveillance, and advanced computational simulations. Second, scientists and engineers attempt to quantify the margin and associated uncertainty, to the extent possible, for each potential failure mode. The assessment process is completed by demonstrating that the margin in performance is greater than the uncertainty in the performance prediction of each potential failure mode of the device.

As described in M.2.2 and M.2.3, there are many unanswered questions regarding fundamental physical data on special nuclear materials that must still be resolved. This is because past experiments, including nuclear tests, did not examine the behavior of materials, either under the extreme conditions associated with nuclear weapons explosions or with the necessary level of precision to resolve certain fundamental physical properties of nuclear weapons materials. The SSP now demands that validated precision physical data on weapons materials be provided in computer models of nuclear weapons performance, which will allow NNSA to assess the effects of aging and engineering modifications on the stockpile. These validated models will allow continued certification of the safety, reliability, and performance of the stockpile without nuclear testing.

The NIF provides a controlled laboratory environment that makes precision and repeatable experiments possible in a way that was not available in underground nuclear testing. Both Los Alamos National Laboratory and LLNL have expressed interest in performing non-ignition and ignition experiments on the NIF using special nuclear materials. Non-ignition experiments can explore the material properties of various forms of plutonium as it is subjected to dynamic pressure and temperature environments when shocked by high-velocity flyer plates or by x-rays produced by the energetic laser beams on the NIF. Detailed information on a material's strength and equation of state can be measured on the NIF at much higher pressures than available on current or planned facilities.

When fusion ignition is achieved on the NIF, an ignition capsule would provide a unique source of x-rays and neutrons that is not available on any other current or planned aboveground experimental facility. The fusion output from an ignition capsule can be used to study nuclear, chemical, and thermomechanical behavior of special nuclear materials, including highly enriched uranium, to provide important data for weapons scientists to use in complex three-dimensional computer models of weapons behavior.

There is a need for a variety of experiments using fissionable and fissile material on the NIF as described in the following paragraphs. Additional details on these experiments are provided in the classified annex (LLNL/NIF 2002b).

- There is a need to perform experiments on the NIF with plutonium or enriched uranium without ignition. These experiments are generally designed to study the equation of state of these materials under conditions where phase changes of the material are expected to occur and to study the effects of aging on the physical properties of these materials. There is also a need for experiments to measure fundamental nuclear physics properties using plutonium or highly enriched uranium that require ignition.

- There is a need to perform experiments on the NIF with lithium hydride, which is not a special nuclear material, with and without ignition. These are materials physics and equation of state experiments designed to address fundamental physical behavior of this material and to allow benchmarking of physical models of the material.
- There is a need to perform experiments on the NIF with depleted uranium with ignition. These experiments require high atomic number materials collocated on the ignition target to enhance the conversion of laser light to x-rays for inertial confinement fusion experiments. There is also a need for experiments that use depleted uranium or highly enriched uranium with ignition to study the physics of these materials.
- There is a need to perform experiments on the NIF with fissionable materials, e.g., thorium-232, and fissile materials, e.g., highly enriched uranium, with ignition. These experiments require the materials to be collocated on the ignition target to provide a measurement of the nuclear processes that occur in an ignition capsule.

There is no NNSA proposal for using a neutron multiplying assembly for experiments on the NIF (Crandall 2002).

The use of special nuclear material on the NIF would allow weapons scientists to accurately evaluate the properties of special nuclear material in the laboratory and to validate weapons test data and refine computer codes to reduce uncertainties.

M.3 DESCRIPTION OF THE NO ACTION ALTERNATIVE, PROPOSED ACTION, AND REDUCED OPERATION ALTERNATIVE

The construction of the NIF conventional facilities is complete and installation of the laser, diagnostic equipment, and target area equipment is in progress. Experiments on the NIF for stockpile stewardship have begun and will continue in parallel with the completion of installation and commissioning of the 192 beam lines. The NIF will transition into full operation following the approval of Critical Decision 4, scheduled to occur in 2008. *National Environmental Policy Act* (NEPA) compliance for conventional facility construction and equipment installation of the NIF is described in the NIF project-specific analysis of the SSM PEIS (DOE 1996a) and was amended by the Supplement Analysis for the use of Hazardous Materials in the NIF Experiments (DOE 1998c) and the Supplemental SSM PEIS (DOE 2001f).

This appendix analyzes the No Action Alternative, Proposed Action, and Reduced Operation Alternative for the NIF. Section M.3 is broken into subsections as follows:

- M.3.1 covers the No Action Alternative, which includes the NIF experiments and operations for which decisions have already been made and provides information on the hazardous and radioactive materials approved for use on the NIF.
- M.3.2 covers the Proposed Action for changes in NIF operations; the use of plutonium, other fissile materials, fissionable materials, and lithium hydride in experiments on the NIF; and the construction and operation of a neutron spectrometer.
- M.3.3 evaluates the Reduced Operation Alternative for the NIF.